Research Techniques for Studying the Brain

Current methods for studying the brain
- Structural imaging
- Functional imaging
- Animal techniques
- Neuropsychological methods

Structural Imaging
- X-Rays
  - Pictures on film
- Computerized Axial Tomography (CAT Scan)
  - Uses a special detector instead of film
- Magnetic Resonance Imaging (MRI)
  - Uses strong magnetic fields and pulses to spin hydrogen atoms in water
  - After spinning, Hydrogen atoms emit transmissions which are picked up by a scanner and constructed into a “picture”

Functional Imaging Techniques
- Direct techniques
  - Electroencephalography-EEG
  - Magnetoencephalography-MEG
- Indirect techniques
  - Positron Emission Tomography-PET
  - Functional Magnetic Resonance Imaging-FMRI
- Non-imaging techniques
  - Transcranial Magnetic Stimulation-TMS
  - Single cell recordings

EEG
- Directly measures the electrical activity from large populations of cells
- Electrical currents pass through the scalp
  - Measured by a large group of electrodes
- Activity closest to the skull is most easily measured

EEG- frequently used during sleep
**EEG - How it works**

- **Pros and Cons of EEG**
  - Good temporal resolution (i.e., very accurate timing)
  - Poor spatial resolution (i.e., inaccurate localization of activity)
    - Electric fields smear as they pass through the skull

**MEG**

- Every electric field (as detected by EEG) also has a magnetic field
- Magnetic fields don’t smear across the skull like electric fields
- Measures information strictly from grooves in the brain (called sulci)
  - Very limited on what it can measure

**Pros and Cons of MEG**

- Only records in sulci
  - Misses information
- Very expensive
- Temporal resolution good
- Spatial resolution better than EEG, not great though

**PET and FMRI**

- Assumes that neuronal activity leads to an increase in blood flow
- Detects the changes in blood flow
- More blood = more neuronal activity

**PET**

- Uses radioactive molecules injected into the blood to measure brain activity
- As radioactive molecules decay, they release positrons
  - Positrons collide with electrons and release gamma rays
  - PET machines detect gamma rays and are able to pinpoint where they came from
- Usually uses radioactive glucose or oxygen
How PET works

- Say you want to study language processing
- Where do we process nouns?
- Run a PET study where you play nouns for your subjects
- What can you conclude?

How PET works

- How do we know that this activation isn’t simply from hearing any sound, not simply nouns?
- We must have a control that is very similar to what we are testing (nouns)
- Maybe use a verb or reversed speech
- Try to eliminate other variables that may be responsible for some of the activations

Have subjects perform two tasks

Compare the activation between the two tasks

Called “subtraction analysis”

Pros and Cons of PET

- Radioactivity- not good
  - Subjects get paid more though
- Spatial sensitivity is quite good- level of 1cm
- Temporal sensitivity not very good- on the level of 1 minute

FMRI

- Uses very strong magnets- 1.5 Tesla- 11 Tesla currently in use
  - 1.5 Tesla has a strength equivalent to 30,000 times the force of gravity
  - 3-4 Tesla is about the “norm”
**FMRI – How it works**

- Quite complicated - usually have full time physicists to work the scanners
- Measure the amount of oxygen in the blood - uses this as a measure of neuronal activity

**FMRI data**

![FMRI data](image)

**Pros and Cons of FMRI**

- Good Spatial Resolution (3-5 mm)
- Decent Temporal Resolution (on the level of 1-2 seconds)
- Inside of a magnet, you can’t do too many different things
- Quite loud (very hard to study auditory system)

**Issues with PET and FMRI**

- Only measures things indirectly
- Measures blood flow, not neuronal activity
- Assumes that increases in neuronal activity requires an increase in blood flow

**TMS**

- Uses a wand to send pulses through the skull and target a brain area
- Can do two things:
  - Send strong short pulses to excite the area targeted
  - Send weaker longer pulses to inhibit the area targeted

**Interesting Note - TMS**

- TMS is actually used on stroke patients
- Doctors believe that after a stroke, the damaged side of the brain tries to repair itself
- The undamaged side of the brain tries to compensate for the damaged side
- This is actually detrimental to the healing of the damaged side
Interesting Note- TMS

- Applying TMS to hinder the undamaged side appears to help the brain heal
- Patients are seeing noted improvements after about 10 sessions (able to count after treatment, when unable to count prior to treatment)

Single cell recordings

- Used extensively in animal studies
- A microelectrode is inserted into brain tissue and recordings of action potentials can be made from nearby neurons, ideally a single neuron.
  - Recordings are typically extracellular (outside of the cell)
- The animal can then be presented with various sensory stimuli, or trained to perform some task, and the effects on neural activity can be monitored

Pros and Cons – Single Cell Recordings

- Advantages: great spatial and temporal resolution
- Disadvantages: sampling only a very small fraction of a functional neural system
- Hubel and Weisel study

Neuropsychological Techniques: Lesion studies

- Correlation of functional deficits with regions of damage
- Both human and animal studies
  - In animals, lesions can be made experimentally
  - In humans, lesions are causes by “experiments of nature”

Lesion studies (con’t)

- Common types of lesions in humans
  - Stroke (A “brain attack”)
    - Ischemic: blockage of blood flow in an artery
    - Hemorrhagic: rupture of an artery
  - Trauma
    - Open vs. closed head injury
  - Tumor
  - Degenerative disease (e.g., alzheimers disease)
- In general, the more focal the lesion, the easier it is to link the site of damage to a behavioral deficit

Neurosurgery Methods

- Direct cortical stimulation
  - Delivery of a small electric current directly on the cortical surface
  - Causes temporary disruption or facilitation of function in cortex being stimulated
  - Used clinically to map function, so that critical regions can be avoided during tissue resection
  - Can be done intra-operatively, or more commonly now, via chronically implanted electrode grids
Neurosurgery methods (con’t)

- Split-brain
  - Sectioning of corpus callosum as a treatment for medically intractable epilepsy
  - Can study the separate contributions of the left and right hemispheres to various abilities/tasks

Neurosurgery methods (con’t)

- WADA procedure
  - Injection of sodium amytal (a barbituate), into one and then the other carotid artery temporarily (5-10min) puts half the brain to sleep allowing neurologists to assess function in the awake hemisphere
Neurosurgery methods (con't)

- General considerations
  - Advantages: better experimental control in some situations, e.g., temporary lesions can be very focal and reversible
  - Disadvantages: all subjects in these subjects are undergoing these procedures because they have a neurological disorder, therefore it is not clear how generalizable the results are.